DOI: 10.31401/WS.2021.proc.12

Interferometer Observations of Type II and Type IV Bursts at 20 and 25 MHz in May 2014

Melnik V.N.[1], Shepelev V.A.[1], Dorovskyy V.V.[1], Brazhenko[2]

[1] Institute of Radio Astronomy, Kharkiv, Ukraine
[2] Institute of Geophysics, Gravimetrical Observatory, Poltava, Ukraine
e-mail: melnik@rian.kharkov.ua

Abstract.

We discuss results of interferometer observations of Type II and Type IV bursts by the radio telescope UTR-2 on 29 May 2014. Type IV burst was initiated by coronal mass ejection (CME) which moved behind the eastern limb with longitude -110° - -120°. The source of Type IV burst was situated at the distance of 30` at both frequencies 20 and 25 MHz and practically coincided with location with CME core. But their sizes were different at these frequencies, approximately 27` and 35` - 40` at 25 and 20 MHz correspondingly. Type II bursts were consisted of sub-bursts for which their sizes and distances were measured. Sub-bursts have sizes from 10` to 28` and were situated at distances from 20` to 45`.

Introduction

Most papers, which discussed sizes and places of sources of different bursts types at low frequencies, were published in 60-80th of the preceding century (Erickson, 1963, Malitson, and Erickson, 1966, Gergely, and Kundu, 1974, 1975, Nelson, and Robinson, 1975, Abranin, et al., 1976,1980, Chen, and Shawhan, 1978, Dulk et al., 1980). At present some papers considered interferometer observations of Type III bursts (Morosan et al., 2014; Melnik et al., 2017; Mann et al., 2018) and herring-born structures of Type II bursts.

Type II bursts are rare phenomenon so their sizes and distances were measured rarely. According to Nelson and Robinson (1975) Type II sources had sizes mainly from 5' to 20' at 40 MHz and their distances at this frequency were changed from 2Rs to 3.2Rs. Chen and Shawhan (1978) obtained 40' for Type II sizes at 26.4 MHz. Recently Dorovskyy et al. (2018) reported sizes and distances of sources of Type II herring-born sub-bursts at frequencies 20-30 MHz. Average sizes were about 15' with smallest ones about 10'. Distances were from 1.5 Rs to 2Rs (Dorovskyy et al., 2018).

Interferometer observations of decameter Type IV bursts were not frequent also. Gergely and Kundu (1975) observed four Type IV bursts at frequencies 20-60 MHz in 1971 with the radio telescope in Clark Lake and obtained their sizes and positions. They remarked that bursts appeared at high frequencies firstly and after that their radio emissions were registered at lower frequencies. All Type IV sources moved outward the Sun from the distances 1.5-1.9 Rs to 2.5-3.5 Rs. At some distances this movement was deceased. Sizes at low frequencies were larger than those at higher frequencies and were as large as 1.4-1.9 Rs. Chen and Shawhan (1978) measured sizes of Type IV sources also and they found that those sizes were not larger than 30' (1.9 Rs) at 26.4 MHz.

In this paper we consider results of interferometer observations of Type II, and Type IV bursts with the UTR-2 radio telescope, which were carried out in observational campaign May-June 2014.

Observations

Observations in May-June 2014 campaign were conducted at UTR-2 radio telescope (Kharkiv, Ukraine), which worked in an interferometer regime, and at URAN-2 (Poltava, Ukraine) radio telescope, which worked in an usual spectrometric regime. As the saying was in (Melnik et al., 2017, 2018b) sections of east-west and north-south arms of UTR-2 radio telescope (Fig.1) were used in the interferometer regime of observations. This allowed forming interferometer bases 225, 450 and 675 m in the east-west direction and 225, 450, 675, 900, 1125, and 1350 m in the north-south direction. On 27-30 May only the east-west arm was used.

The dynamic spectrum of solar radio emission from 8:44 to 11:25 UT on 29 May 2014 is shown in Fig.2. We see that there was a group of powerful Type III bursts with maximum fluxes of $10^3 s.f.u.$ from 8:45 to 8:55 UT. Polarization of these bursts were not large, only 10%. Frequency drift rates of Type III bursts were about 3 MHz/s. These bursts were generated by active region NOAA 2079, which was situated behind east limb with the longitude angle -110° - -120° (Fig.3a). A flare in this region began at 8:42 UT and ended at 9:12 UT (http://www.helioviewer.org/). Its maximum was at 8:57 UT. So the group of Type III bursts was apparently initiated by this flare. This flare was a cause of CME also, whose mass was $6.2 \cdot 10^{15} g$ and velocity of 398 km/s. We connect the Type IV burst observed in frequency band of 16-60 MHz (Fig.2) with this CME. The maximum duration of Type IV burst was about 2 hours at 33 MHz. The duration was shorter at lower frequencies. This Type IV burst was weak, its maximum flux was about $10 s.f.u.$ and polarization was up to 40%.

Type II bursts (Fig.2) were imposed on the Type IV burst. There were four of them. They had different drift rates and frequency bands. Type II burst (1) (Fig.2) was registered in the frequency band 17-22 MHz from 9:06 to 9:10 UT. Its drift rate, duration, flux and polarization were 60 kHz/s, 40 s, $50 s.f.u.$ and 20% correspondingly. Other Type II bursts were weaker with fluxes not higher than $10 s.f.u.$ Their polarizations were not higher than 10%. Drift rates were 60, 20 and 20 kHz/s for 2, 3 and 4 Type II bursts (Fig.2) correspondingly. The whole durations of these bursts were more than 2 minutes. All four Type II bursts consisted of sub-bursts with durations of 2-20 s.

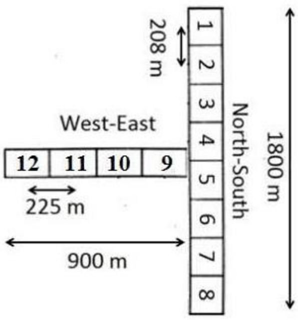

Fig.1. Scheme of the radio telescope UTR-2, which consists of 8 North-South sections and 4 West-East sections.

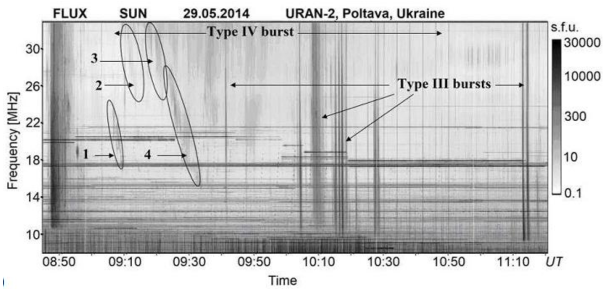

Fig.2. Dynamic spectrum of solar radio emission from 8:43 to 11:23 UT on 29 May 2014 according to URAN-2.

Type II bursts

The first burst (1) (Type II burst) was registered from 9:06 to 9:10 UT in the frequency band 17-22 MHz (Fig.2). We observed it in the interferometer regime at 20 MHz. This burst had fine structure as separate clouds. There were four such sub-bursts with durations 4, 3, 6 and 5 s at 20 MHz. The total duration of Type II burst was 30 s and this is smaller than durations of standard decameter Type II bursts at this frequency (Melnik, et al., 2005). Fluxes of sub-bursts were not high - $17 s.f.u.$, $108 s.f.u.$, $38 s.f.u.$ and $19 s.f.u.$ Polarizations of these bursts were not high also, about 1-3%. As a whole Type II burst had frequency drift rate approximately 60 kHz/s. Sizes were following 10`, 20`, 27` and 24` and they were at distances 25`, 28`, 28` and 30` correspondingly. This time the front of CME was situated at this distance too. So we conclude that the burst (1) was generated by the shock ahead of CME.

Next Type II burst (burst 2) (Fig.2) observed from 9:10 to 9:13 UT at 25 MHz. This burst consisted of three sub-bursts with fluxes of $1.3 s.f.u.$, $1.9 s.f.u.$, $3.9 s.f.u.$ Polarizations of sub-bursts were practically zero. Frequency drift rate of this Type II burst the same as for burst 1, about 60 MHz/s. According to interferometer observations sizes of sub-bursts were 15`, 13` and 15`. Distances for all sub-bursts were the same and equaled 35`($2.2 \cdot R_S$).

At times 9:19 - 9:21 and 9:21 - 9:26 UT there were two Type II bursts (3 and 4 bursts) at 25 MHz (Fig.2). At the first period of time different separate sub-bursts had fluxes up to $10 s.f.u.$ Sizes of all sub-bursts were in the range 13`-18` and they were at 30` ($1.9 \cdot R_S$) from the center of the Sun. At the second interval (9:21 - 9:26 UT) fluxes of sub-bursts were $10-30 s.f.u.$ They were a little larger, with sizes up to 20` and they placed at distances about 40`- 45` ($2.5-2.8 \cdot R_S$). Approximately, at this distance at 9:21 - 9:26 UT the CME nose is situated. Thus, we conclude that burst (4) was generated by nose shock and 3 burst was generated by flank shock. As a whole both bursts (3) and (4) drifted with drift rate of 20 kHz/s.

Type IV burst

Type IV burst was observed from 9:10 to 10:50 UT at 33 MHz. Profiles of flux and polarization are shown in the Fig.3. Its maximum flux is about $10 s.f.u.$ and maximum polarization is 40%.We see that flux maximum achieved at about 9:40 UT and polarization maximum was at 10:15 UT, more than half hour latter. Type II bursts were against Type IV burst and we cannot recognize drift of Type IV front. But we can say definitely that Type IV burst continued from 9:18 to 10:25 UT and from 9:19 to 9:25 UT at 25 and 20 MHz correspondingly. Fig.4 shows sizes and places of Type IV burst at 20 and 25 MHz

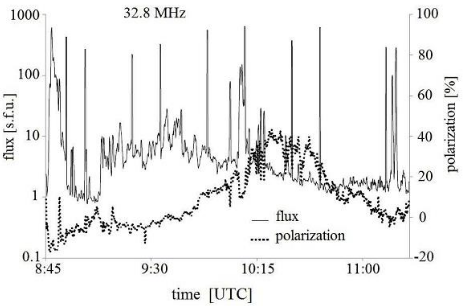

Fig.3. Flux (solid line) and polarization (dotted line) of Type IV burst at 32.8 MHz according to URAN-2 radio telescope.

according to our interferometer observations. We see that centers of Type IV radio emission at both frequencies were situated at the same distances, about 30`, and only at the end of burst at 25 MHz the center of radio emission became closer to the Sun (Fig.4a). Type IV size at 25 MHz was about 27` and it decreased to 20` to the end of the burst. At frequency of 20 MHz, the size was about 37` all time of its existence. Sizes of Type IV burst at 20 and 25 MHz against CME at 9:48 UT are shown in Figure 5. We see that at this time Type IV source coincides with CME on position and size. Later the source of Type IV burst does not move, but CME continues to move with velocity of about 400km/s and we conclude that this Type IV burst is a stationary one.

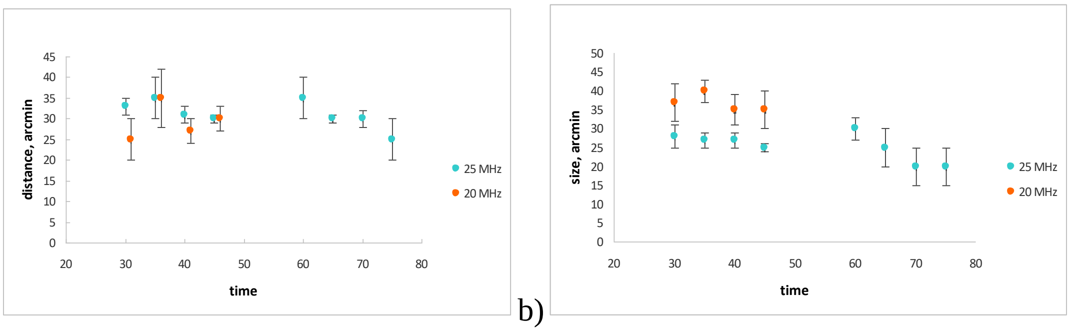

Fig.4. Positions (a) and sizes (b) of Type IV source at 20 and 25 MHz.

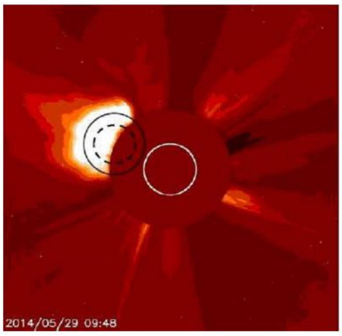

Fig.5. CME at 9:48 UT and source of Type IV burst at frequency of 20 and 25 MHz this time.

Discussion

All discussed Type II bursts have fine structure in the form of sub-bursts that is standard phenomenon for decameter Type II bursts (Melnik et al. 2005). Sub-bursts sizes change from 10` to 30`. Their positions show that they were governed by flank shock. Their brightness temperatures $10^7 K$-$10^9 K$ are close to those of Type III bursts (Melnik et al., 2017). Supposing that frequency drift rate is described by equation ($df/dt = f/2 \cdot dn/ndr \cdot v$) we find that velocity is higher than CME velocity and correspondingly shock velocity. In our opinion this high velocity is velocity of shock region, which generates radio emission registered by radio telescope but it is not the same shock region. Such situation was already marked in the paper (Dorovskyy et al., 2018) and can present some sort of arc eye effect. As a whole Type II burst had drift rate about 60 kHz/s that give linear velocity about 2000 km/s in Newkirk model [Newkirk, 1961]. This radio emission escaped the distance of $1.9R_S$. The region, which is responsible for Type IV radio emission against CME, is shown in the Fig.5. We see that the CME core can be source of this radio emission. But if in the case of moving Type IV bursts this core moves, in our case the CME core does not move and it situated at the distance of 30`. So we can conclude that this is a stationary Type IV burst. Centers of radio emission at both frequencies 20 and 25 MHz are the same. At the same time sizes at these frequencies are different, 27` and 37` at 25 and 20 MHz correspondingly. We can conclude that moving CME after time 11:00 UT is shock which was initiated by CME core at first stage of movement. The CME core had energy enough to reach the distance 30` and after that core stopped. Such behavior was marked also by Gergely, and Kundu (1974). Kundu and Gergely observed movement of CME to distances 3.5 Rs and after that movement deceased. Our Type IV burst began to go out at first at low frequencies and latter at higher frequencies. Size to the end of the radio emission at 25 MHz decreased to 20` and its brightness temperature at this frequency was $3.2\cdot10^7 K$. At the beginning the brightness temperatures of Type IV burst were $3.5\cdot10^7 K$ and $1.8\cdot10^7 K$ at 25 and 20 MHz correspondingly. The range of radio emission frequency of Type IV burst is not very high, only from 18 to 45 MHz. If we suppose that mechanism of radio emission is plasma one (Melnik et al., 2018) and radio emission is fundamental then we can consider that the highest frequency, 45 MHz, escapes the center of CME core and the lowest frequency, 19 MHz, is radiated at periphery of the core. It means that densities in the center and at the periphery are $n_c = 2.5\cdot10^7 cm^{-3}$ and $n_{19} = 4.9\cdot10^6 cm^{-3}$ correspondingly. From the equation $n(r) = n_c \exp(-\alpha r)$ (Melnik et al., 2018) we derive that $\alpha = 1.45 / R_{\odot}$ having in mind that at $R_{20} = 18'$ core density is equaled to $n_{20} = 4.9\cdot10^6 cm^{-3}$ and at the radius $R_{25} = 13'$ the core density is $n_{25} = 7.7\cdot10^6 cm^{-3}$ and in the center of the core density is $n_c = 2.5\cdot10^7 cm^{-3}$ (it corresponds to plasma frequency of 47 MHz). The mass of the CME core is $2.9\cdot10^{16} g$. This value is higher than the mass from the SOHO catalogue (https://cdaw.gsfc.nasa.gov/CME_list/). If we suppose that radio emission was generated at the second harmonic then mass of the CME core equals $6\cdot10^{15} g$ which is closed to (https://cdaw.gsfc.nasa.gov/CME_list/). So we conclude that in this case the radio emission of the CME core occurred at the second harmonic.

References

Abranin, E.P., Bazelian, L.L., Goncharov, N.I., Zaitsev, V.V., Zinichev, V.A., Rapoport, V.O., Tsybko, I.G.(1976) Angular sizes of sources of solar radio bursts in the decameter Range, Soviet Astron. 19, 602, 1976.

Abranin, E.P., Bazelian, L.L., Goncharov, N.I., Zaitsev, V.V., Zinichev, V.A., Rapoport. V.O., Tsybko, I.G. (1980), Positions of Solar Storm Burst Sources by Observations with a Heliograph Based on the UTR-2 Antenna at 25 MHz. Solar Phys. 66, 393, 1980.

Chen, H.S.-L., Shawhan, S.D. (1978), Structure and evolution of solar radio bursts at 26.4 MHz. Solar Phys. 57, 205, 1978.

Dorovskyy, V., Melnik, V., Konovalenko, A., Brazhenko, A., Rucker, H. (2018), Spatial properties of the complex decameter type II burst observed on 31 May 2013. Sun and Geosphere 13, 25.

Dulk, G.A., Gary, D. E., Suzuki, S. (1980), The position and polarization of Type V solar bursts, Astron. Astrophys. 88, 203, 1980.

Erickson, W.C. (1963) High-Resolution Studies of Type III Solar Emission at 11.4-MeterWavelength. J. Geophys. Res. 68, 3169, 1963.

Gergely, T.E., Kundu, M.R. (1974) Decameter Type IV Bursts Associated with Coronal Transients. Solar Phys. 34, 433, 1974.

Gergely, T.E., Kundu, M.R. (1975) Decameter Storm Radiation Solar Phys. 41, 163, 1975.

Malitson, H.H., Erickson, W.C. (1966) Observations of Type III and Type IV Solar Radio Bursts at 26.3 Mc/s. Astrophys. J. 144, 337, 1966.

Mann, G., Breitling, F., Vocks, C., Aurass, H., Steinmetz, M., Strassmeier, K.G., Bisi, M.M., Fallows, R.A., Gallagher, P., Kerdraon, A., Mackinnon, A., Magdalenic, J., Rucker, H., Anderson, J., Asgekar, A., Avruch, I.M., Bell, M.E., Bentum, M.J., Bernardi, G., Best, P., Birzan, L., Bonafede, A., Broderick, J.W., Br • uggen, M., Butcher, H.R., Ciardi, B., Corstanje, A., de Gasperin, F., de Geus, E., Deller, A., Duscha, S., Eisloffel, J., Engels, D., Falcke, H., Fender, R., Ferrari, C., Frieswijk, W., Garrett, M.A., Grie_meier, J., Gunst, A.W., van Haarlem, M., Hassall, T.E., Heald, G., Hessels, J.W.T., Hoeft, M., Horandel, J., Horneffer, A., Juette, E., Karastergiou, A., Klijn, W.F.A., Kondratiev, V.I., Kramer, M., Kuniyoshi, M., Kuper, G., Maat, P., Marko, S., McFadden, R., McKay-Bukowski, D., McKean, J.P., Mulcahy, D.D., Munk, H., Nelles, A., Norden, M.J., Orru, E., Paas, H., Pandey-Pommier, M., Pandey, V.N., Pizzo, R., Polatidis, A.G., Rafferty, D., Reich, W., Rottgering, H., Scaife, A.M.M., Schwarz, D.J., Serylak, M., Sluman, J., Smirnov, O., Stappers, B.W., Tagger, M., Tang, Y., Tasse, C., ter Veen, S., Thoudam, S., Toribio, M.C., Vermeulen, R., van Weeren, R.J., Wise, M.W., Wucknitz, O., Yatawatta, S., Zarka, P., Zensus, J.A.: (2018) Tracking of an electron beam through the solar corona with LOFAR. Astron. Astrophys. 611, A57, 2018.

Mel'Nik, V.N., Konovalenko, A.A., Abranin, E.P., Dorovskyy, V.V., Stanislavsky, A.A., Rucker, H.O., Lecacheux, A. (2005), Solar sporadic radio emission in the decametre waveband. Astronomical and Astrophysical Transactions 24, 391, 2005.

Melnik, V.N., Brazhenko, A.I., Konovalenko, A.A., Dorovskyy, V.V., Rucker, H.O., Panchenko, M., Frantsuzenko, A.V., Shevchuk, M.V. (2018a) Decameter Type IV Burst Associated with a Behind-the-limb CME Observed on 7 November 2013. Solar Phys. 293, 53, 2018.

Melnik, V.N., Shepelev, V.A., Poedts, S., Dorovskyy, V.V., Brazhenko, A.I., Rucker, H.O.(2018b), Interferometric Observations of the Quiet Sun at 20 and 25 MHz in May 2014, Solar Phys. 293, 97, 2018.

Melnik, V., Shepelev, V., Brazhenko, A., Dorovskyy, V., Rucker, H., Stefaan, S. (2017) Interferometer Observations of Solar Type III Bursts by the Radio Telescope UTR-2. Sun and Geosphere 12, 105, 2017.

Morosan, D.E., Gallagher, P.T., Zucca, P., Fallows, R., Carley, E.P., Mann, G., Bisi, M.M., Kerdraon, A., Konovalenko, A.A., MacKinnon, A.L., Rucker, H.O., Thid_e, B., Magdalenic, J., Vocks, C., Reid, H., Anderson, J., Asgekar, A., Avruch, I.M., Bentum, M.J., Bernardi, G., Best, P., Bonafede, A., Bregman, J., Breitling, F., Broderick, J., Br • uggen, M., Butcher, H.R., Ciardi, B., Conway, J.E., de Gasperin, F., de Geus, E., Deller, A., Duscha, S., Eisloffel, J., Engels, D., Falcke, H., Ferrari, C., Frieswijk, W., Garrett, M.A., Grie_meier, J., Gunst, A.W., Hassall, T.E., Hessels, J.W.T., Hoeft, M., H • orandel, J., Horner, A., Iacobelli, M., Juette, E., Karastergiou, A., Kondratiev, V.I., Kramer, M., Kuniyoshi, M., Kuper, G., Maat,P.,Markoff, S., McKean, J.P., Mulcahy, D.D., Munk, H., Nelles, A., Norden, M.J., Orru, E., Paas, H., Pandey-Pommier, M., Pandey, V.N., Pietka, G., Pizzo, R., Polatidis, A.G., Reich, W., Rottgering, H., Scaife, A.M.M., Schwarz, D., Serylak, M., Smirnov, O., Stappers, B.W., Stewart, A., Tagger, M., Tang, Y., Tasse, C., Thoudam, S., Toribio, C., Vermeulen, R., van Weeren, R.J., Wucknitz, O., Yatawatta, S., Zarka, P. (2014), LOFAR tied-array imaging of Type III solar radio bursts. Astron. Astrophys. 568, A67, 2014.

Nelson, G.J., Robinson, R.D. (1975), Multi-Frequency Heliograph Observations of Type II Bursts, Proceedings of the Astronomical Society of Australia 2, 370, 1975.

Newkirk, J. Gordon (1961), The Solar Corona in Active Regions and the Thermal Origin of the Slowly Varying Component of Solar Radio Radiation. Astrophys. J. 133, 983, 1961.

Thompson, A.R., Moran, J.M., Swenson, G.W. Jr. (2001), Interferometry and Synthesis in Radio Astronomy, 2nd Ed., John Wiley and Sons, New York, 2001.